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PATENT SPECIFICATION

Application Date: July 14, 1943. No. 11422/43. **572,169**

Complete Specification Left: Aug. 14, 1944.

Complete Specification Accepted: Sept. 26, 1945.

PROVISIONAL SPECIFICATION

Improvements in or relating to Apparatus for Cooling or Attemperating Oil or other Viscous Liquids

We, CLIFFORD STUART STEADMAN, a British Subject, of 24, Kidderminster Road, Bridgnorth, Shropshire, and IMPERIAL CHEMICAL INDUSTRIES LIMITED, a British Company, of Imperial Chemical House, Millbank, London, S.W.1, do hereby declare the nature of this invention to be as follows:—

This invention relates to oil coolers for the engines of aircraft and other vehicles and particularly to oil coolers of the kind in which the oil flowing through the cooling matrix is distributed over a number of oil paths not all of the same length.

Aircraft engine oil coolers are usually of the honeycomb type which comprises a plurality of thin-walled tubular elements assembled within a casing of cylindrical or other curvilinear form the arrangement being such that the cooling air flows through the tubular elements while the hot oil flows through spaces between them within the casing. Such oil coolers are usually provided with a by-pass which is controlled by a spring-loaded valve adapted to enable the oil to by-pass the cooler when the matrix is choked with congealed oil. Usually also a system of shutters or louvres is provided to control the air-flow through the cooler, the said shutters being adjusted automatically, as by a thermostatic device located in the oil-flow from the cooler. The curvilinear form of the assembly, whilst highly desirable or even essential in certain circumstances where high internal pressures are involved, has certain disadvantages, for example the major portion of the oil tends to follow the paths of least resistance—i.e the shortest paths from the oil inlet to the outlet, and the flow of oil through other portions of the cooler is consequently relatively sluggish and prolonged. A hitherto uncontrollable phenomenon commonly known as "coring" sometimes occurs when an aircraft is flying a very cold atmosphere, in which the temperature of the oil issuing from the cooler is too high although it is known that the oil is not by-passing the cooler. It is now established that in such circumstances of low air temperature, the oilflow through those parts of the matrix having high resistance to oilflow may fall off or cease entirely, resulting in loss of effective cooling in that part of the matrix. This has the effect of causing the outlet oil from the cooler (which includes the oil from the portions of the matrix functioning normally) to increase in temperature, and in consequence the thermostatic controlling device thereupon operates to admit more cooling air through the shutters when in fact a reduced flow of air is required. Various alternative methods of automatically controlling the shutters have been proposed, as for example by oil pressure responsive means in the oil inlet to the cooler but such methods have not succeeded in overcoming the difficulties arising from coring.

The object of the present invention is to provide an improved oil cooler of the kind described in which the aforesaid difficulties are overcome in a simple and effective manner.

According to the present invention we provide an improved heat exchange device of the kind referred to in which means are provided to distribute the oil substantially uniformly throughout the matrix, the said means being adapted to secure a substantially uniform resistance to flow as between the several oil-paths, irrespective of differences in the lengths thereof.

The said means may be such as to increase in inverse proportion the resistance to oilflow through the shorter oilpaths or such as to decrease in inverse proportion the resistance to oilflow through the longer oilpaths, or may be a combination of such means. For example, a plurality of perforate baffles may be inserted at intervals across the path of the oil flowing through the matrix, the size and/or pitch of the perforations in the said baffles being varied so that the flow of oil in the region of the shorter oilpaths is impeded in inverse proportion to the lengths of the said paths. Alternatively the matrix may be constructed in such manner that spaces are formed at intervals between adjacent elements in the same oil paths, the number and/or width of the spaces being ad-

justed to reduce the resistance to oilflow as required.

Several embodiments of our invention are illustrated in the accompanying drawings in which

Figure 1 is a diagrammatic cross-sectional view of one form of heat exchange device constructed in accordance with the present invention.

Figure 2 is a plan view of a portion of the device illustrated in Figure 1.

Figure 3 is a diagrammatic cross-sectional view of another form of heat exchange device constructed in accordance with the invention.

Figure 4 is a diagrammatic cross-sectional view of still another form of heat exchange device constructed in accordance with the invention.

Referring to Figures 1 and 2 of the drawings, an oil cooler comprises a matrix of tubular elements 1 mounted within a cylindrical casing 2 which is provided with an oil inlet 3 and outlet 4, and with inlet and outlet header compartments 5 and 6 respectively. The matrix is divided longitudinally by a baffle 7, a common header compartment 8 being provided at the base of the matrix to convey oil around the end of the baffle 7 from the inlet to the outlet side thereof. Longitudinal perforate baffles 9 extend at right angles from the central baffle 7 on the inlet and outlet sides thereof, the said baffles 9 terminating within the matrix at positions substantially equidistant from the casing 2. The said baffles are provided with rows of perforations 10 of which the diameter increases progressively in each row towards the outer edges of the baffles whilst the pitch of the perforations remains substantially constant. The actual diameter and spacing of the perforations are arranged to suit the characteristics of a particular cooler, so that the flow of oil by the shortest path therethrough—i.e. by the straight path from the oil inlet to the bottom edge of the baffle 7 and from the said bottom edge of the oil outlet is impeded to an extent such that the total resistance to oilflow by this path is substantially equal to the flow of oil by the longest path through the cooler around the outer edges of the perforate baffles, and so that the oil flow through intermediate paths is proportionately impeded. Thus the oilflow is distributed substantially uniformly over the cross section of the available oil path throughout the matrix.

A modified form of oil cooler is illustrated in Figure 3, which comprises an annular matrix 11 housed between concentric casings 12 and 13, an oil inlet 14 and outlet 15, and inlet and outlet headers 16 and 17 respectively, the said headers being separated by a wall 18. Perforate baffles 18a are provided which extend partway across the matrix from the inner casing 13 towards the outer casing 12. The said baffles 18a are similar to the baffles 9 described with reference to Figures 1 and 2 of the drawings and are adapted to function in similar manner to distribute the oilflow substantially uniformly over the cross section of the total available oil path between the oil inlet and outlet.

In still another form of oil cooler illustrated in Figure 4, the matrix comprises a series of unitary portions 19 housed between concentric casings 20 and 21, and separated by intermediate headers 22. An oil inlet 23 and outlet 24, and inlet and outlet headers 25 and 26 respectively are provided. All the oil paths through each portion of the matrix are of substantially the same length and resistance to oil flow, and consequently, since there is substantially no cooling effected in the intermediate headers, and substantially no resistance to oil flow therethrough, the oil flow is distributed substantially uniformly over the cross-section of the total available oil path between the oil inlet and oil outlet.

Whilst we have illustrated and described several embodiments of the invention by way of example, it will be understood that the invention is not limited to the described embodiments, and that other methods of carrying the invention into effect may be devised which fall within the scope of the invention.

Dated the 14th day of July, 1943.

E. A. BINGEN,
Solicitor for the Applicants.

COMPLETE SPECIFICATION

Improvements in or relating to Apparatus for Cooling or Attemperating Oil or other Viscous Liquids

We, CLIFFORD STUART STEADMAN, a British Subject, of 24, Kidderminster Road, Bridgnorth, Shropshire, and IMPERIAL CHEMICAL INDUSTRIES LIMITED, a British Company, of Imperial Chemical House, Millbank, London, S.W.1, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to oil coolers for

the engines of aircraft and other vehicles and particularly to oil coolers of the kind in which the oil flowing through the cooling matrix is distributed over a number of oil paths not all of the same length.

Aircraft engine oil coolers are usually of the honeycomb type which comprises a plurality of thin-walled tubular elements assembled within a casing of cylindrical or other curvilinear form, the arrangement being such that the cooling air flows through the tubular elements while the hot oil flows through spaces between them within the casing. The curvilinear form of the assembly, whilst highly desirable or even essential in certain circumstances where high internal pressures are involved, has certain disadvantages, for example the major portion of the oil tends to follow the paths of least resistance—i.e. the shortest paths from the oil inlet to the outlet, and the flow of oil through other portions of the cooler is consequently relatively sluggish and prolonged.

Aircraft engine oil coolers may also be of the secondary surface type which comprises a plurality of thin-walled tubular elements, usually of flattened cross-section, adapted to form a plurality of passages through which the hot oil can flow between header compartments, the said tubes being spaced laterally to permit the passage of cooling air around and between them. In one construction of this type of cooler the tubes are spaced apart by corrugated strips or sheets which together with portions of the tube walls constitute a series of airways with the airflow substantially at right angles to the oil flow in the tubes. In the application of this type of cooler to curved power plant installations the cooler will have to take the form of for example part of a segment of a circle, and the oil paths on the inner radii of the segment will be considerably shorter, and consequently offer less resistance to the flow of oil, than those on the outer radii. In this case likewise the major portions of the oil will tend to follow the paths of least resistance and the flow of oil through other portions of the cooler will consequently be relatively sluggish and prolonged.

This inequality in oil flow distribution through the matrix, which is evident even under isothermal conditions of oil flow, will be greatly accentuated under heat transfer conditions, since the oil passing down the higher resistance paths will be flowing at a lower rate and hence will be cooled more than that flowing down a low resistance path, resulting in a higher mean viscosity in the high resistance path and hence a further reduction in proportional flow. The variation in oil flow distribution will increase with the nett amount of cooling done by the air, i.e. increase in cooling air flow and, in particular, decrease in air inlet temperature will both cause greater variation in oil flow distribution. With very low air inlet temperatures, as for example when an aircraft is flying in a very cold atmosphere, the oil flow distribution may become so bad that oil flow may fall off very considerably or cease entirely in certain parts of the matrix. This phenomenon, hereinafter referred to as "congealing", is accompanied by a considerable increase in oil pressure drop across the matrix and by a fall in the specific performance of the cooler, i.e. heat dissipated per unit temperature difference between air inlet temperature and mean oil temperature, which may result in inadequate oil cooler performance.

The object of the present invention is to provide an improved oil cooler of the kind described in which the problem of "congealing" is overcome in a simple and effective manner.

According to the present invention we provide an improved heat exchange device of the kind referred to in which means are provided to distribute the oil substantially uniformly throughout the matrix, the said means being adapted to secure a substantially uniform resistance to flow as between the several oil paths, irrespective of differences in the lengths thereof.

The said means may be such as to increase in inverse proportion the resistance to oilflow through the shorter oil paths or such as to decrease in inverse proportion the resistance to oilflow through the longer oilpaths, or may be a combination of such means.

For example, in a honeycomb type cooler, a plurality of perforate baffles may be inserted at intervals across the path of the oil flowing through the matrix, the size and/or pitch of the perforations in the said baffles being varied so that the flow of oil in the region of the shorter oilpaths is impeded in inverse proportion to the lengths of the said paths. Alternatively the matrix may be constructed in such manner that spaces are formed at intervals between adjacent tubular elements in the same oil paths, the number and/or width of the spaces being adjusted to reduce the resistance to oilflow as required.

In a secondary surface type cooler the pitch of the oil tubes may be increased progressively from the longer to the shorter side in such manner that the increased cooling of the shorter tubes effects a proportionate increase in the viscosity of the oil flowing therethrough to an extent

sufficient substantially to equalise the flow resistance in all the tubes in the matrix. Instead of altering the pitch of the tubes, equalisation of flow resistance may be effected by adjustment of the mechanical resistance to oilflow by variation of the reinforcing and turbulating means in the oil tubes themselves. Thus for example, when perforated corrugated strip is used for this purpose, the number and/or diameter of the perforations may be decreased progressively across the cooler from the longer to the shorter tubes. Alternatively the pitch of the corrugations may be decreased across the cooler in the same manner. Alternatively again a combination of one type of strip having a lower resistance to oil flow and another type having a greater resistance to oil flow may be used in each tube, the relative proportion of the strip having greater resistance increasing progressively across the matrix from the longer to the shorter tubes. To facilitate manufacture and assembly, it will in some cases be sufficient for the purposes of the invention to subdivide the oil tubes into a number of groups, the tubes in each group being provided with internal members of the same kind and the variation in the internal members taking place from group to group across the matrix.

Several embodiments of our invention, showing its application to oil coolers of the honeycomb type, are illustrated in the drawings accompanying the Provisional Specification in which

Figure 1 is a diagrammatic cross-sectional view of one form of heat exchange device constructed in accordance with the present invention.

Figure 2 is a plan view of a portion of the device illustrated in Figure 1.

Figure 3 is a diagrammatic cross-sectional view of another form of heat exchange device constructed in accordance with the invention.

Figure 4 is a diagrammatic cross-sectional view of still another form of heat exchange device constructed in accordance with the invention.

Referring to Figures 1 and 2 of the drawings, an oil cooler comprises a matrix of tubular elements 1 mounted within a cylindrical casing 2 which is provided with an oil inlet 3 and outlet 4, and with inlet and outlet header compartments 5 and 6 respectively. The matrix is divided longitudinally by a baffle 7, a common header compartment 8 being provided at the base of the matrix to convey oil around the end of the baffle 7 from the inlet to the outlet side thereof. Longitudinal perforate baffles 9 extend at right angles from the central baffle 7 on the inlet and outlet sides thereof, the said baffles 9 terminating within the matrix at positions substantially equidistant from the casing 2. The said baffles are provided with rows of perforations 10 of which the diameter increases progressively in each row towards the outer edges of the baffles whilst the pitch of the perforations remains substantially constant. The actual diameter and spacing of the perforations are arranged to suit the characteristics of a particular cooler, so that the flow of oil by the shortest path therethrough—i.e. by the straight path from the oil inlet to the bottom edge of the baffle 7 and from the said bottom edge to the oil outlet is impeded to an extent such that the total resistance to oilflow by this path is substantially rqual to the flow of oil by the longest path through the cooler around the outer edges of the perforate baffles, and so that the oil flow through intermediate paths is proportionately impeded. Thus the oilflow is distributed substantially uniformly over the cross-section of the available oil path throughout the matrix.

A modified form of oil cooler is illustrated in Figure 3, which comprises an annular matrix 11 housed between concentric casings 12 and 13, an oil inlet 14 and outlet 15, and inlet and outlet headers 16 and 17 respectively, the said headers being separated by a wall 18. Perforate baffles 18a are provided which extend partway across the matrix from the inner casing 13 towards the outer casing 12. The said baffles 18a are similar to the baffles 9 described with reference to Figures 1 and 2 of the drawings and are adapted to function in similar manner to distribute the oilflow substantially uniformly over the cross-section of the total available oil path between the oil inlet and outlet.

In still another form of oil cooler illustrated in Figure 4, the matrix comprises a series of unitary portions 19 housed between concentric casings 20 and 21, and separated by intermediate headers 22. An oil inlet 23 and outlet 24, and inlet and outlet headers 25 and 26 respectively are provided. All the oil paths through each portion of the matrix are of substantially the same length and resistance to oil flow, and consequently, since there is substantially no cooling effected in the intermediate headers, and substantially no resistance to oil flow therethrough, the oil flow is distributed substantially uniformly over the cross-section of the total available oil path between the oil inlet and oil outlet.

Further embodiments of our invention, showing its application to oil coolers of the secondary surface type, are illustrated in the accompanying drawings, in which

Figure 5 is a diagrammatic cross-sectional view of a curvilinear secondary surface type oil cooler constructed in accordance with the present invention.

Figure 6 is a diagrammatic cross-sectional view of another form of curvilinear secondary surface type oil cooler constructed in accordance with the invention.

Figure 7 is a diagrammatic sectional side elevation of part of one of the oil tubes in Figure 6.

Figure 8 is an enlarged plan view at the section A—A of the oil tube illustrated in Figure 7.

Figure 9 is a perspective view of a small portion of the corrugated internal member shown in Figure 8.

Referring to Figure 5 of the drawings, an oil cooler comprises a matrix of flattened tubular elements 27 serving as oilways spaced apart by corrugated members 28 to form airways, the matrix being mounted within a casing 29 in the shape of a segment of a cylindrical annulus provided with oil inlet 30 and outlet 31 and inlet and outlet header compartment 32 and 33 respectively. The tubes 27 are provided with internal perforated corrugated members (not shown) extending substantially throughout their width and depth for the purpose of reinforcement and promoting turbulence of the oil flowing through. The pitch of the tubes 27 is increased progressively from the longer to the shorter side, with corresponding increase in the depth of the airway corrugations, in such manner that the increased cooling of the shorter tubes effects a proportionate increase in the viscosity of the oil flowing therethrugh to an extent sufficient substantially to equalise the hydraulic resistance in all the tubes in the matrix.

Referring to Figures 6, 7, 8 and 9, an oil cooler comprises a matrix of equidistant flattened tubular elements 34 serving as oilways spaced apart by corrugated members 35 to form airways, mounted in a casing of the same shape as that illustrated in Figure 5. The tubes 34 are provided with internal corrugated members extending substantially throughout their width and depth. The said internal corrugated members in the outside tube 34a consist of a plain corrugated strip with a number of small perforations to promote oil turbulence and those in the inside tube 34b consist of a doubly corrugated strip shown in Figure 9 having rows of alternate re-entrant corrugations 36 and 37. In the intermediate tubes varying lengths of plain corrugated strip and doubly corrugated strip are so combined that the overall flow resistance of each tube is substantially equal to that of the other tubes in the matrix. This is shown diagrammatically in Figure 7 where the part designated by the numeral 39 and shown in diagonal shade lines represents the doubly corrugated strip, and the part 38 shown in vertical shade lines represents a plain corrugated strip.

Whilst we have illustrated and described several embodiments of the invention by way of example, it will be understood that the invention is not limited to the described embodiments, and that other methods of carrying the invention into effect may be devised which fall within the scope of the invention.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. Oil cooler of the kind described in which means are provided to distribute the oil substantially uniformly throughout the matrix, the said means being adapted to secure a substantially uniform resistance to flow as between the several oil paths irrespective of differences in the lengths thereof.

2. Oil cooler in accordance with Claim 1, in which means are provided to increase in inverse proportion the resistance to oilflow through the shorter oil paths.

3. Oil cooler in accordance with Claim 1, in which means are provided to decrease in inverse proportion the resistance to oilflow through the longer oil paths.

4. Oil cooler of the honeycomb type in accordance with Claim 1 or 2, in which a plurality of perforate baffles are inserted at intervals across the path of the oil flowing through the matrix, the size and/or pitch of the perforations in the said baffles being varied so that the flow of oil in the region of the shorter oil paths is impeded in inverse proportion to the lengths of the said paths.

5. Oil cooler in accordance with Claim 4, in which the perforate baffles do not extend across the oil paths of greatest length.

6. Oil cooler of the honeycomb type in accordance with Claim 1 or 3, in which spaces are formed at intervals between adjacent tubular elements in the same oil paths, the number and/or width of the said spaces being adjusted to reduce the resistance to oilflow of the longer oil paths to the required extent.

7. Oil cooler of the secondary surface type in accordance with Claim 1 or 2, in which the pitch of the oil tubes is increased progressively across the matrix in such manner that the increased cooling of the shorter tubes effects a proportionate

increase in the viscosity of the oil flowing therethrough to an extent sufficient substantially to equalise the flow resistance in all the tubes in the matrix.

8. Oil cooler of the secondary surface type in accordance with Claim 1, 2 or 3, in which equalisation of the flow resistance is effected by variation of the reinforcing and turbulating means in the oil tubes.

9. Oil cooler in accordance with Claim 8, in which the reinforcing and turbulating means comprise a perforated corrugated strip, the number and/or diameter of the perforations being decreased progressively across the matrix from the longer to the shorter tubes.

10. Oil cooler in accordance with Claim 8, in which the reinforcing and turbulating means comprises a perforated corrugated strip, the pitch of the corrugations being decreased across the matrix from the longer to the shorter tubes.

11. Oil cooler in accordance with Claim 8, in which a combination of one type of reinforcing and turbulating means having a lower resistance to oilflow and another type having a greater resistance to oilflow is used in each tube, the relative proportion of the means having greater resistance increasing progressively across thr matrix from the longer to the shorter tubes.

12. Oil cooler in accordance with any of Claims 8—11, in which the oil tubes are subdivided into a number of groups, the tubes in each group being provided with reinforcing and turbulating means of the same kind and the variation in the said means taking place from group to group across the matrix.

13. Oil cooler of the honeycomb type substantially as hereinbefore described with reference to the drawings accompanying the Provisional Specification.

14. Oil cooler of the secondary surface type substantially as hereinbefore described with reference to the accompanying drawings.

Dated the 14th day of August, 1944.

E. A. BINGEN,
Solicitor for the Applicants.

Leamington Spa: Printed for His Majesty's Stationery Office, by the Courier Press.—1946.

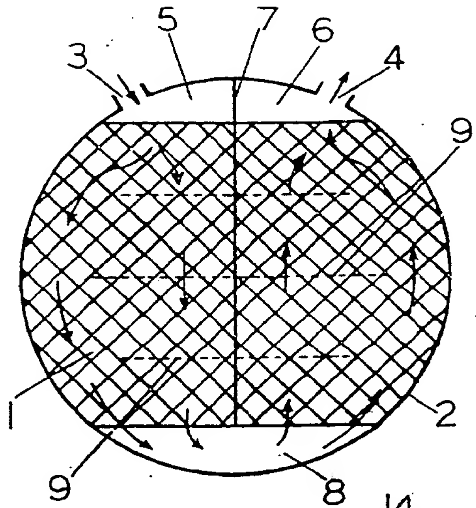

FIG. 1

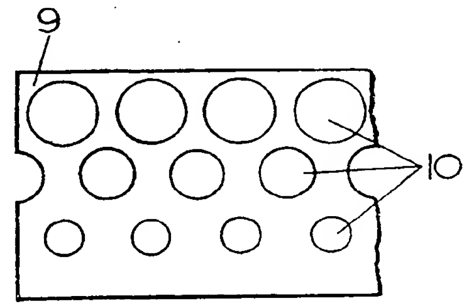

FIG. 2

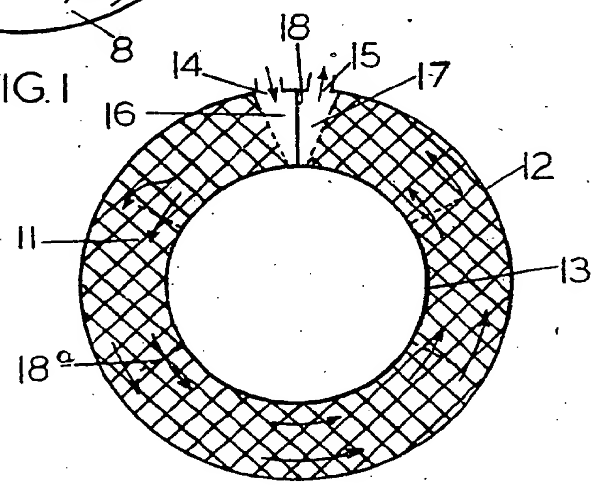

FIG. 3

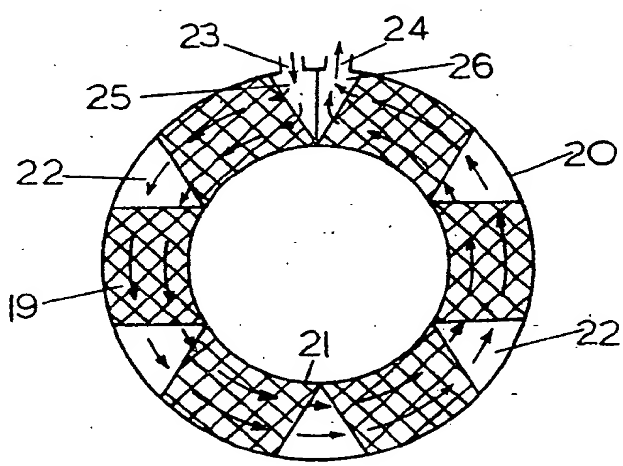

FIG. 4

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[This Drawing is a reproduction of the Original on a reduced scale.]

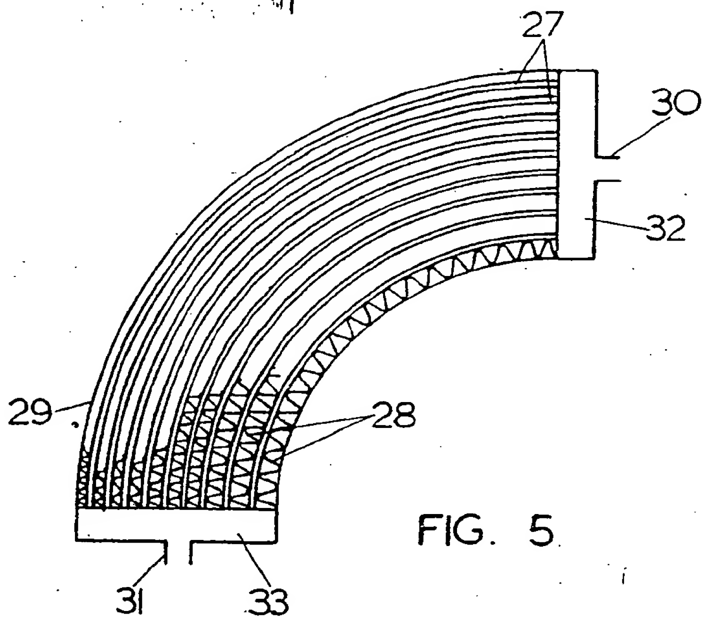

FIG. 5

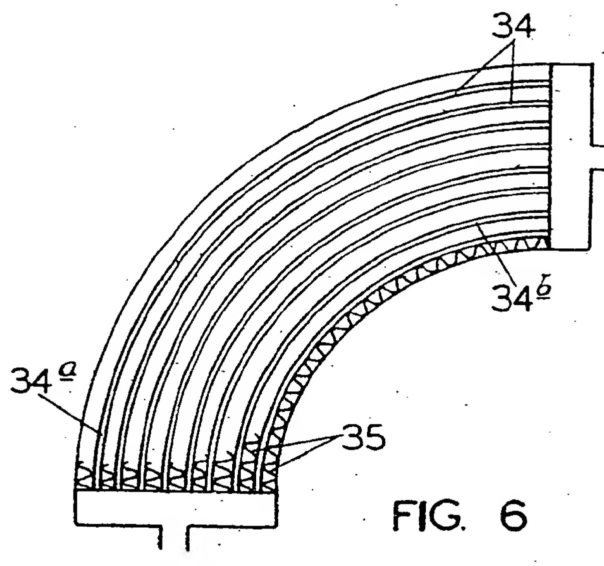

FIG. 6

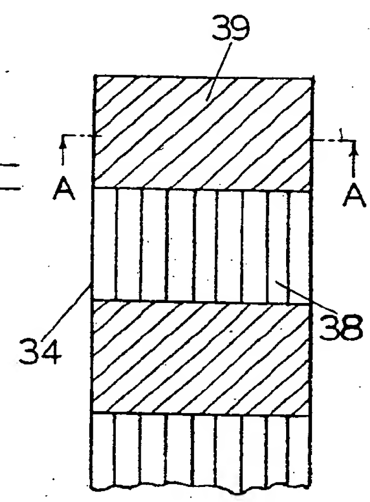

FIG. 7

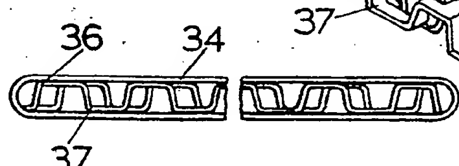

FIG. 8

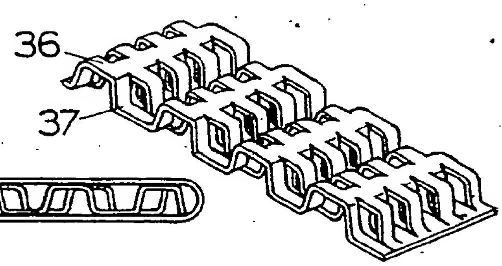

FIG. 9

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